Navy Personnel Research and Development Center
San Diego, California 92152-7250 TR-98-4 July 1998

A Technique for Assessing the Congruence Between Visual Metaphors and Mental Models

Jean MacMillian
David J. Getty
B. Charles Tatum
Gary A. Ropp

19980803 057

Approved for public release; distribution is unlimited.

DTIC QUALITY INSPECTED 1

NPRDC-TR-98-4

July 1998

A Technique for Assessing the Congruence Between Visual Metaphors and Mental Models

Jean MacMillian
David J. Getty
BBN Corporation

B. Charles Tatum
Gary A. Ropp
Navy Personnel Research and Development Center

Reviewed and approved by
Dennis Schurmeier

Released by
W. M. Keeney
Commander, U.S. Navy
Commanding Officer

and

Murray W. Rowe
Technical Director

Approved for public release;
distribution is unlimited.

Navy Personnel Research and Development Center
53335 Ryne Road
San Diego, California 92152-7250

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is limited to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding the burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE July 1998	3. REPORT TYPE AND DATE COVERED October 1994-September 1996

4. TITLE AND SUBTITLE
A Technique for Assessing the Congruence Between Visual Metaphors and Mental Models

5. FUNDING NUMBERS
Program Element: 0602233N
Work Unit: RM33M20

6. AUTHOR(S)
Jean MacMillian, David J. Getty, B. Charles Tatum, Gary A. Ropp

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Navy Personnel Research and Development Center
53335 Ryne Road
San Diego, California 92152-7250

8. PERFORMING ORGANIZATION AGENCY REPORT NUMBER
NPRDC-TR-98-4

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Office of Naval Research
800 North Quincy Street
Arlington, VA 22217-5000

10. SPONSORING/MONITORING

11. SUPPLEMENTARY NOTES
Functional Area:
Product Line:
Effort:

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12B. DISTRIBUTION CODE
A

13. ABSTRACT *(Maximum 200 words)*

This research project tested a method for measuring the congruence between mental models and visual metaphors. A hydraulic system was used as a visual metaphor for a Navy school-planning process. The hydraulic system was designed as a reasonable approximation of the users' mental model of the process. The congruence between the hydraulic metaphor and the users' presumed mental model was tested using a Metaphor Rating Sheet. The sheet contained different concepts of hydraulics and school planning as rows (e.g., tanks, pipes, school capacity, school inputs), and functional properties of hydraulic and school planning as columns (e.g., holding capacity, flow rate). Different analyses of the ratings showed that there was a close parallel between the different hydraulic and school-planning concepts and their functional properties. For example, a faucet (a component of a hydraulic system) and the concept of loss rates (a school planning concept) both share the functional property of "exit out of a system." The methods developed in this study can be used to measure the "fit" between a designers visual metaphor and the users mental model. However, the methods do not tell the designer whether the visual metaphor will facilitate use of the software.

14. SUBJECT TERMS
Visual metaphors, mental models, display design, user interface, human-computer systems

15. NUMBER OF PAGES
24

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UNLIMITED

Foreword

Research discussed in this report is part of an exploratory development project entitled "Information Delivery System Design for Personnel Force Management" (Program Element 0602233N, Project RM33M20). The report describes a technique for quantifying the relationship between a graphical metaphor of a software application and the mental model of the user. The technique, based on similarity ratings between properties of a metaphor and the user's concept of the software, was developed by researchers at the Navy Personnel Research and Development Center with assistance from BBN Corporation, Systems and Technologies Division (Contract No. N0244-95-D-0281). The visual metaphor in this study was a hydraulic system that represented the process of "A" School planning. This metaphor was also used in a previous study conducted during this project (MacMillian Freeman, Tatum, & Ropp, 1998). The study suggests that software designers should align their graphical metaphors with the mental models of the users, and proposes a useful technique to accomplish this objective.

W. M. KEENEY
Commander, U. S. Navy
Commanding Officer

MURRAY W. ROWE
Technical Director

Summary

Problem

Designers of software applications and systems sometimes attempt to increase user-friendliness by developing metaphors. For example, Apple computers use a desktop metaphor with their operating system, and Microsoft uses a typewriter metaphor with their popular word processor. But, do these metaphors match the mental models that users have for these same applications? In other words, does the metaphor correspond to the way the user conceives of the software designer's application?

Objective

This research attempts to develop a quantitative technique for measuring the congruence between a graphical metaphor and the user's mental model. If such a technique is feasible, then software designers could be more confident that the way they think about the application matches the way the user thinks about the application. Such a technique would be valuable for both the designer and the user. Designers could create more user-friendly software. Users would find the software easier to learn and operate.

Approach

A hydraulic system—a system of tanks, pipes, and valves—was used as a visual metaphor for a Navy school-planning process. (The visual metaphor was implemented in a software program known as SKIPPER). The hydraulic system was designed as a reasonable approximation of the users' mental model of the process. The congruence between the hydraulic metaphor and the users' presumed mental model was tested using a "Metaphor Rating Sheet." The sheet contained different concepts of hydraulics and school planning as rows (e.g., tanks, pipes, school capacity, school inputs), and functional properties of hydraulic and school planning as columns (e.g., holding capacity, flow rate). The user was required to rate the correspondence between columns and rows on a 5-point rating scale.

Results

Analysis of the ratings showed that there was a close parallel between the different hydraulic and school-planning concepts and their functional properties. For example, a faucet (a component of a hydraulic system) and the concept of loss rates (a school planning concept) both share the functional property of "exit out of a system." The pattern of the findings revealed not only that the hydraulic metaphor was appropriate for the task, but that the rating technique could reliably measure the congruence between visual metaphor and the user's mental model.

Conclusions

The methods developed in this study can be used to measure the "fit" between a designer's visual metaphor and the user's mental model. The methods can also be adapted

to compare different metaphors and determine their relative congruence with the users' conceptual model. However, the methods do not tell the designer whether employing a visual metaphor will facilitate the use of any particular application. There may be a strong congruence between the metaphor and a user's mental model, but this is still no guarantee that the metaphor will help the user.

Recommendations

1. Software and system designers should use the technique reported here (or some variation on this method) to determine whether the visual metaphors they use are congruent with the mental model of the user. If there is low congruence, the designers should consider different metaphors. If there is high congruence (as was shown in this study) the designers can be confident that their metaphors may help users understand and operate applications and systems.

2. Future work should focus on refining this technique and developing variations that allow comparisons between alternative metaphors.

Contents

Introduction

Use of the term "mental model" has become widespread in discussions of how people understand and interact with complex systems. Mental models have been proposed as a mechanism by which users of a computer system acquire and apply knowledge about how to interact with the system (Moray, 1996; Carroll & Olson, 1990; Preece et al., 1994). Two types of mental models may be useful in interacting with a complex system: structural or conceptual models that specify "how it works" and functional models that specify "how to do it." Conceptual models are useful in understanding complex interactions and making predictions, while functional models link actions to outcomes, but need not explicitly represent the causal mechanisms behind the link (Preece et al., 1994).

Mental models are often described in terms of imagery (Johnson-Laird, 1983), and there is considerable evidence that the formation and use of mental models draws on components of the human visual system (Kosslyn, 1989). Because mental models are believed to have a strong visual component, it is only natural to think about using visual images or pictorial metaphors to represent or support them in computer displays. It has often been suggested that metaphors are useful in the design of user interfaces, and, to the extent that they are congruent with underlying conceptual models of a system, that such metaphors can be helpful in learning to use a complex system (Carroll, Mack, & Kellogg, 1990). Pictorial metaphors are useful because of parallelism between the pictorial representation and the thing being represented. This parallelism implies that the representation and the thing are from different domains (or they could not be parallel) and that there is some resemblance between them, that is, they have particular aspects or properties that are parallel (Dent-Read, Klein, & Eggleston, 1994).

Human factors scientists trying to evaluate the usefulness of visual metaphors in display design face a complex measurement problem as illustrated in Figure 1. It is relatively straightforward to measure whether the presence of a visual metaphor in a display design improves the users' understanding of causal relationships or the users' performance in accomplishing tasks. What is lacking is a method for assessing *why* a particular visual metaphor is or is not useful. Metaphors may fail for at least three reasons. First, pictorial metaphors, in general, may be a poor method for improving performance or increasing understanding for a specific application. Second, the metaphor may be poorly implemented in the specific interface, e.g., it may be difficult to access or may not engage the attention of the user. Third, metaphors may fail because the specific metaphor used is a poor representation, i.e., it is not congruent with the user's mental model. In order to separate the third cause of failure from the first two, we need to measure the congruence between the properties of the visual metaphor and the properties of the user's mental model—we need a method for comparing two intangibles.

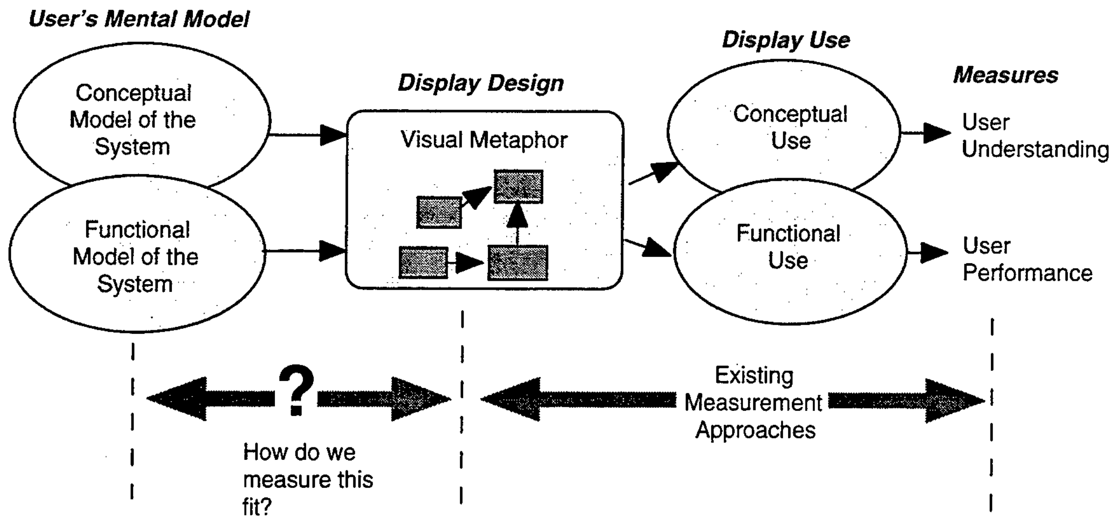

Figure 1. Measurement challenge for evaluating visual metaphors in display design.

Method

We developed a measurement method for assessing the congruence between the perceived properties of a visual metaphor for a complex system and the properties of the users' conceptual model of that system. This method was developed as part of an overall evaluation of a "User Coach," a software tool somewhat like a "Wizard" designed to help inexperienced Navy personnel learn to use a manpower planning tool (MacMillian & Freeman, 1996). The method allows an evaluation of the congruence of the metaphor and the users' mental models that is independent of the evaluation of the value of the metaphor in improving user understanding or performance.

Domain

The Navy faces a complex manpower planning problem in keeping its many technical specialty areas staffed at desired levels. The number of new recruits that should be enrolled for training in each specialty every year (entry-level training is provided by "A" Schools) depends on a number of interacting factors. These factors include: (1) the number of specialists needed each year, (2) the number of specialists developed through on-the-job training, (3) the expected rates at which members of the specialty will leave the Navy, (4) the dropout rate for the training schools, and (5) the length of training schools. The Navy Personnel Research and Development Center (NPRDC) has developed a manpower planning tool to help Navy planners develop "A" School training plans. This tool uses a complex mathematical model to predict the required number of trainees based on input from the user. Users new to the tool often have trouble understanding how to use it and in interpreting its results.

Because of the difficulties encountered in learning to use the planning tool, NPRDC developed a User Coach to help inexperienced users. The Coach provides step-by-step procedural instructions, text explanations, and a pictorial representation of the factors that affect "A" School enrollment requirements, shown in Figure 2. This pictorial representation uses a hydraulic flow metaphor—a series of tanks, pipes, funnels, and faucets—to show users how various factors affect the needed school inputs. Each planning factor is represented by a hydraulic element. For example, water in a tank is used to show the "inventory" (the number of individuals in a technical specialty) in each year. The tank has a desired fill line showing the number of individuals needed in that specialty. The pictorial representation, called "The Big Picture," was provided in an attempt to improve users' conceptual understanding of the complex interrelationships among the factors affecting school enrollment requirements.

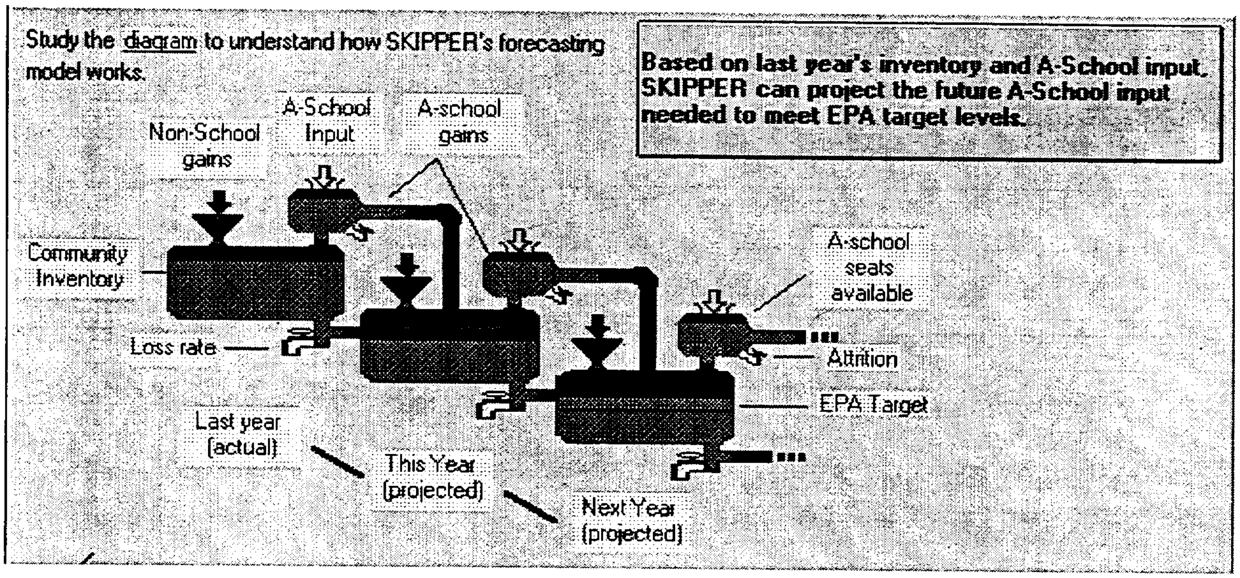

Figure 2. The Big Picture.

The hydraulic flow metaphor was developed based on interviews with users of the planning tool in which they described their mental models for manpower planning (Tatum, 1994). The interviews asked the users to describe an analogy or metaphor that they use to help them do their job and use the planning tool. Over 70 percent of those interviewed reported using a hydraulic (fluid) or pneumatic (air pressure) metaphor to describe their "A" School planning activities and use of the software tool.

Approach

We evaluated the effectiveness of the User Coach by having users develop plans with and without the Coach, and with and without the Big Picture. As part of this evaluation, we asked users to complete a Metaphor Rating Matrix designed to collect data that would allow us to analyze the congruence between users' mental models of the "A" School planning process and the visual metaphor used in the Big Picture.

The rating matrix, shown in Figure 3, measures the correspondence between the properties of the various hydraulic elements shown in the picture and the properties of the various planning factors as they exist in the user's mental model of planning. The pictorial elements in the Big Picture were chosen because they had properties that corresponded to the properties of the concepts that they represented. For example, a dripping faucet was used to show attrition from the Navy—individuals "leak out" over time. We developed a list of the properties that we believed were shared by the hydraulic system elements and the "A" School planning concepts. These are the properties underlying the choice of the hydraulic metaphor—the aspects of the metaphor believed to be parallel to the user's mental model. These properties formed the columns of the matrix. The rows were formed by the hydraulic elements shown in the Big Picture, e.g., "faucet" or "tank" and by the abstract concepts used in planning, e.g., "inventory." We asked each subject to rate the applicability of each of the properties to each of the hydraulic elements and to each of the planning concepts. The correspondence between subjects' ratings of the properties for a hydraulic element and their ratings for the concept represented by that element indicates how well each concept was represented by the corresponding pictorial element.

Metaphor Score Sheet   Subject: __________ Session Code: __________ Date: __________

In the table below, please rate how well each of the phrases at the top of the table describes the components or concepts listed at the left. These components or concepts involve: 1) the flow of water in a hydraulic system, or 2) the "flow" of enlisted personnel through the A-School and into the inventory

Provide your ratings by filling in each open (white) cell below with a number from 1 to 5, where: 1=not at all applicable
5=very applicable

How well does each phrase to the right ----> describe the components or concepts below?	Involves movement	Involves one-way movement	Has a holding capacity	Has a flow capacity	Has a fill level	Has a flow rate	Involves input into a system	Involves exit out of a system	Connects parts of a system
Components of a hydraulic system									
Faucet									
Water through a faucet									
Tank									
Water in a tank									
Funnel									
Water through a funnel									
Pipe									
Water through a pipe									
A-School planning concepts									
Loss rates (from inventory)									
A-School attrition									
Non-school gains									
Inventory									
A-School capacity									
A-School inputs (accessions)									

Figure 3. Metaphor Rating Sheet.

Results

Twenty-one subjects completed the task of rating the applicability of each of nine properties for each of eight different hydraulic system components and six different "A" School planning concepts. Subjects rated each property on a 5-point scale where "1" indicated that the property was not at all applicable and "5" indicated that it was very applicable.

Mean Property Ratings

The mean rating of each property for each component or concept, averaged over subjects, is shown in Table 1. Properties with high mean applicability ratings (greater than or equal to a threshold value of 4.0)[1] are shown in bold in the table. For example, the *faucet* component was judged by subjects to have two highly applicable properties among the nine: "has a flow capacity" and "involves exit out of a system" with mean ratings of 4.05 and 4.19, respectively. The number of properties judged to be highly applicable ranged from a minimum of one (water in a tank, funnel, and inventory) to a maximum of four (water through a faucet and loss rate) across the eight hydraulic components and six planning concepts.

Table 1

Mean rating of Property Relevance to Hydraulic System Components and "A" School Planning Concepts

	Involves Movement	Involves One-way Movemet	Has a Holding Capacity	Has a Flow Capacity	Has a Fill Level	Has a Flow Rate	Involves Input Into a System	Involves Exit Out of a System	Connects Parts of a System
Components of a Hydraulic System									
Faucet	2.90	3.67	1.48	**4.05**	1.14	3.29	3.19	**4.19**	1.62
Water through a faucet	**4.52**	**4.52**	1.29	3.19	1.33	**4.86**	3.19	**4.52**	1.38
Tank	1.24	1.24	**5.00**	1.29	**4.95**	1.62	1.38	1.33	2.19
Water in a tank	2.05	1.43	2.57	1.86	**4.00**	1.57	1.52	1.38	1.67
Funnel	2.90	3.86	1.71	3.67	1.76	2.86	**4.24**	2.24	2.71
Water through a funnel	**4.14**	**4.48**	1.29	2.67	1.33	**4.67**	3.81	2.76	1.86
Pipe	2.71	2.10	2.52	**4.14**	1.43	3.19	3.10	3.14	**4.76**
Water through a pipe	**4.71**	3.24	1.33	3.05	1.81	**4.57**	3.57	3.71	2.81
"A" School Planning Concepts									
Loss rates	**4.05**	**4.19**	1.14	2.81	1.57	**4.05**	1.67	**4.86**	1.52
"A" School attrition	**4.05**	**4.38**	1.10	2.86	1.38	3.86	1.48	**4.86**	1.71
Non-school gains	**4.05**	**4.33**	1.10	3.10	1.57	3.71	**4.90**	1.67	1.76
Inventory	2.00	1.19	3.71	1.90	**4.10**	1.86	2.00	2.05	1.86
"A" School capacity	1.71	1.48	**4.52**	2.57	**4.10**	1.76	2.81	1.29	2.05
"A" School inputs	**4.00**	3.95	2.05	3.00	2.05	3.43	**4.86**	1.71	1.52

[1] Users provided ratings on a scale from 1 to 5. On this scale, 3 is the midpoint. We would not expect the mean ratings to be at the highest value of 5, so 4 seemed to be a reasonable threshold for a "highly applicable" rating.

Correlation Between Hydraulic System Components and "A" School Planning Concepts

We performed several different analyses to determine the correspondence between the pattern of mean property ratings for each hydraulic system component relative to the pattern of mean property ratings for each "A" School planning concept. In a first analysis, we calculated the Pearson's correlation coefficient between the vector of mean property values for each hydraulic system component and the vector of mean property values for each "A" School planning concept. The results of this analysis are shown in Table 2. For example, the mean property ratings for faucet (2.90, 3.67, 1.48, etc.) were correlated with the mean property rating for loss rate (4.05, 4.19, 1.14, etc.), which yielded the $r = .77$ in Table 2. Correlation coefficients that are significant with a probability of less than or equal to 0.05 of occurring by chance are indicated by one or more asterisks. Correlations that are significant with a probability less than or equal to 0.01 are shown also in bold type.

Table 2

Pearson's Correlation Coefficients Between Components of a Hydraulic System and "A" School Planning Concepts

	"A" School Planning Concepts					
	Loss Rates	**"A" School Attrition**	**Non-school Gains**	**Inventory**	**"A" School Capacity**	**"A" School Inputs**
Components of a Hydraulic System						
Faucet	0.77 *	0.77 *	0.54	**-0.74** *	-0.72 *	0.43
Water through a faucet	**0.92** ***	0.90 ***	0.65	**-0.71** *	-0.80 **	0.55
Tank	-0.67 *	-0.69 *	-0.70 *	**0.95** ***	0.89 ***	-0.52
Water in a tank	-0.52	-0.55	-0.49	**0.90** ***	0.77 *	-0.35
Funnel	0.20	0.21	0.87 ***	**-0.76** *	-0.46	0.79 *
Water through a funnel	0.69 *	0.67 *	0.88 ***	**-0.76** *	-0.71 *	0.80 **
Pipe	-0.06	-0.02	-0.03	**-0.50**	-0.36	-0.18
Water through a pipe	0.74 *	0.72 *	0.68 *	**-0.73** *	-0.83 **	0.55

Component-concept match used in metaphor.
* p < 0.05.
** p < 0.01.
*** p < 0.005.

Number of Property Matches Between Hydraulic System Components and "A" School Planning Concepts

Another way to examine the correspondence between the pattern of property ratings for hydraulic system components and "A" School planning concepts is by counting up the number of properties for a pair that are in agreement. We used a mean property rating of 4.0 as a threshold for determining whether a given property was judged to be applicable to a component or concept. Thus, if a property had a mean applicability rating below 4.0, it was assigned a "not applicable" label; if its mean rating was 4.0 or above, it was assigned an "applicable" label. Then, for each hydraulic component, planning concept pair, we counted the number of properties that were in agreement—either both "applicable" or both "not applicable." Since there were nine properties altogether, the maximum property match score is nine and the minimum is zero. The results are shown in Table 3. For each "A" School concept, arrayed horizontally, we have bolded and underlined the score(s) for the hydraulic system component(s) that received the highest number of property matches.

Table 3

Number of Property Matches (of nine possible) Between Components of a Hydraulic System and "A" School Planning Concepts

	"A" School Planning Concepts					
	Loss Rates	**"A" School Attrition**	**Non-school Gains**	**Inventory**	**"A" School Capacity**	**"A" School Inputs**
Components of a Hydraulic System						
Faucet	5	6	4	6	5	5
Water through a faucet	**9**	**8**	6	4	3	5
Tank	3	4	4	8	**9**	5
Water in a tank	4	5	5	**9**	8	6
Funnel	4	5	**7**	7	6	**8**
Water through a funnel		7	**7**	5	4	6
Pipe	8	4	4	6	5	5
Water through a pipe	7	6	6	6	5	7

Component-concept match used in metaphor.

Discussion

Adequacy of the Property Set

The set of properties rated by the subjects for their applicability to each hydraulic system component and "A" School planning concept appear to have been adequate as a descriptor set in the following ways. Scanning the mean property ratings shown in Table 1, one can see that each of the nine properties was rated as highly applicable to at least one of the components or concepts, and also as highly inapplicable (a mean rating less than 2.0) to at least one other component or concept. Thus, each property was discriminating across the set of components and concepts. Furthermore, for each component and concept, there was at least one property that was judged to be highly applicable and at least one other that was judged to be highly inapplicable.

Correspondence Between Hydraulic System Components and "A" School Planning Concepts

If we focus our attention on only those hydraulic components and planning concept pairs that are highly correlated (those shown in bold in Table 2), then we see that there is at least one hydraulic system component that corresponds well as a metaphor for each of the "A" School planning concepts, as indicated by a high positive correlation. Only one of the hydraulic system components—pipe—fails to be highly correlated with any of the "A" School planning concepts.

Interestingly, there is a failure by the subjects to discriminate between a *tank* and *water in a tank* as metaphors for the *"A" School inventory*. Both are highly correlated with *inventory*, suggesting that subjects may have thought of a *tank* not just as the container capable of holding water, but as the vessel and contained water combined. Similarly, both *funnel* and *water through a funnel* were equally highly correlated with *non-school gains*, suggesting that the *funnel* was regarded as including the fluid that flowed through it.

Not every planning concept had a unique corresponding component in the hydraulic system. For example, both *loss rates* and *"A" School attrition* had *water through a faucet* as the most highly correlated hydraulic system component.

Similar conclusions may be drawn generally from the counts of property matches shown in Table 3. The hydraulic system component that represents the best match with each "A" School planning concept, as determined by the number of matching properties, is the same as determined by the correlation coefficients, with only two minor exceptions. The best match for *inventory* in terms of counts is *water in a tank* rather than *tank*, and the best match for *"A" School inputs* is *funnel* rather than *water through a funnel*.

Conclusions

Overall, the results show a high degree of correspondence between the properties of the "A" School planning concepts and the properties of the hydraulic components that were chosen to represent them in the visual metaphor. Water through a faucet was used to represent both "A" School attrition and loss rates; a tank represented the capacity of the "A" School; water in the tank represented inventory; and water through a funnel represented non-school gains and "A" School inputs. In each case, given the set of hydraulic components with which we were working, we seem to have chosen the best possible match between components and concepts. We conclude that our metaphor was a good one, i.e., corresponded well to users' conceptual models of "A" School planning. Our results do not necessarily indicate that another completely different metaphor might not have been better, but the measurement method that we developed could be used to assess other metaphors in order to compare their relative "fit" with the users' conceptual models.

Our measurement method allows us to differentiate between the "quality" of the metaphor used, measured in terms of its fit to users' conceptual models, and the usefulness of the metaphor in the interface. Interestingly, the evaluation results (MacMillian and Freeman, 1996; MacMillian, Freeman, Tatum, & Ropp, 1997) indicate that the conceptual use of the visual metaphor in the User Coach was not especially helpful in increasing new users' understanding of "A" School planning concepts. The mean score on a "concepts quiz" that tested users' understanding of the relationships among planning concepts was not significantly higher for users who were shown the metaphor (12.3 out of a maximum score of 15) than for users who did not see the metaphor (10.9 out of 15). Also, the mean time to complete the first planning task was 17.1 minutes for users who viewed the Big Picture, and 13.5 minutes for users who did not. The extra time required to study the pictorial metaphor did not produce a measurable increase in conceptual understanding.

We conclude that the metaphor was a good one, but that its use in the Coach—in an attempt to increase conceptual learning—was unsuccessful. Perhaps metaphors are not as helpful for conceptual use as for functional use in interface designs. We have some confidence, however, based on our evaluation, that a better metaphor would not have improved understanding. Although exposure to the metaphor as implemented did not improve users' conceptual understanding, our results demonstrate that the metaphor was congruent with the users' mental models.

References

Carroll, J. M., Mack, R. L., & Kellogg, W. A. (1990). Interface metaphors and user interface design. In M. Helander (Ed.) *Handbook of human-computer interaction.* Amsterdam: North Holland.

Carroll, J. M. & Olson, J. R. (1990) Mental models in human-computer interaction. In M. Helander (Ed.) *Handbook of human-computer interaction.* Amsterdam: North Holland.

Dent-Read, C., Klein, G., & Eggleston, R. (1994). Metaphor in visual displays designed to guide action. *In Metaphor and Symbolic Activity.* Norwood, NJ; Lawrence Erlbaum Associates, p. 211-232.

Johnson-Laird, P. N. (1983). *Mental Models.* Cambridge, MA: Harvard University Press.

Kosslyn, S. M. (1989). Seeing and imagining in the cerebral hemispheres: A computational approach. In A. Collins, & E. E. Smith, (Eds.) *Readings in cognitive science.* San Mateo, CA: Morgan Kaufman Publishers, Inc.

MacMillian, J., & Freeman, B. (1996). *SKIPPER coach evaluation: Final technical report.* Document prepared for Navy Personnel Research and Development Center (Contract Number N00244-95-D-0281, BBN Report No. 8152), Cambridge, MA: BBN Corporation.

MacMillian, J. Freeman, B., Tatum, B. C., & Ropp, G. A. (1998). *Evaluation of a software user coach for manpower planning* (NPRDC TR 98-5). San Diego, CA: Navy Personnel Research and Development Center.

Moray, N, (1996). A taxonomy and theory of mental models. *In Proceedings of the Human Factors and Ergonomics Society 40th Annual Meeting*, 164-168.

Preece, J., Rogers, Y., Sharp, H., Benyon, D., Holland, S., & Carey, T. (1994). *Human-computer interaction.* Wokingham, UK: Addison-Wesley Publishing Company.

Tatum, B. C. (1994). *Summary of interviews with enlisted community managers.* Unpublished manuscript.

Distribution List

AISTA (PERI II), Army Research Institute
Assistant Deputy Chief of Naval Operations (N1B)
Assistant Secretary of the Navy (Manpower and Reserve Affairs)
Assistant Secretary of the Navy (Manpower and Reserve Affairs) (OASN) (M&RA)
Center for Naval Analyses (Dr. John J. Cymrot)
Chief of Naval Personnel (PERS-00H)
Commander in Chief, U.S. Atlantic Fleet (N1)
Commander in Chief, U.S. Pacific Fleet (N1)
Commander, Space and Naval Warfare Systems Command (SPARWAR-00)
Commanding Officer, Naval Air Warfare Center (Technical Library) (Code 72) (5)
Commanding Officer, Naval Air Warfare Center, Training Systems Division, Orlando
Commanding Officer, Space & Naval Warfare Systems Center, San Diego
Commanding Officer Space & Naval Warfare Systems Center, San Diego (Code D0141)
Commanding Officer, Navy Air Warfare Center (NAWC-TSD)
Commanding Officer, Sea-Based Weapons and Advanced Tactics School, Pacific
Deputy Assistant Secretary of the Navy (Manpower and Reserve Affairs)
Deputy Chief of Naval Operations (M&P) (N1)
Deputy Chief of Naval Research (Code 01) (Dr. Fred Saalfield)
Deputy Under Secretary of the Navy, A&T (R&E)
Director of Education (N2)
Director of Research, U.S. Naval Academy
Director of Training and Education Division (N71)
Director, Army Research Institute, Alexandria, VA (PERI-ZT)
Director, Cognitive and Neural Science and Technology Division (Code 342) (Dr. Willard S. Vaughn, Jr)
Director, Defense Activity for Nontraditional Education Support, Pensacola, FL
Director, Defense Personnel Security Research and Education Center
Director, Enlisted Assignment Division (PERS-40)
Director, Manpower Personnel and Training Info (N16)
Director, Navy Reserve Information Systems Office (NRISO) (Robert A. Duley)
Enlisted Plans and Career Management Division (PERS-22)
Head, Human Factors Division (Code 26)
Head, Manpower Personnel Training Branch (N813)
Headquarters Air Education and Training Command (HQ AETC), Randolph Air Force Base, TX
Human Resources Directorate, Technical Library, AL/HR-SDKL Brooks AFB, TX
Naval Postgraduate School
Office of Naval Research (Code 34), (Dr Anna Johnson-Winegar)
Office of the Director, Test & Evaluation and Technology Requirements (N091)
Office of Training Technology (OTT) (N75)

Distribution List (Continued)

Pentagon Library
Program Officer (Code 342) (Dr. Steele)
Program Officer (Code 342) (Dr. Susan Chipman)
Program Officer (Code 342) (Dr. Terry Allard)
Program Officer (Code 342) (Jan Dickieson)
Public Affairs Office (PERS-05)
Defense Technical Information Center (DTIC) (4)